Aug. 2, 1955 E. J. DIEBOLD 2,714,709

TRANSFORMER COOLING MEANS

Filed March 29, 1951 3 Sheets-Sheet 1

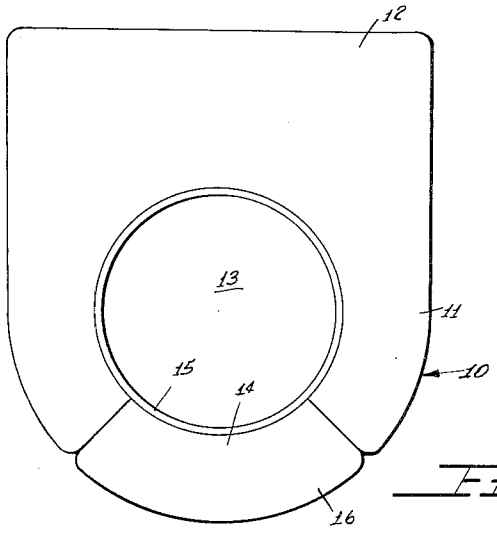


FIG. 1.

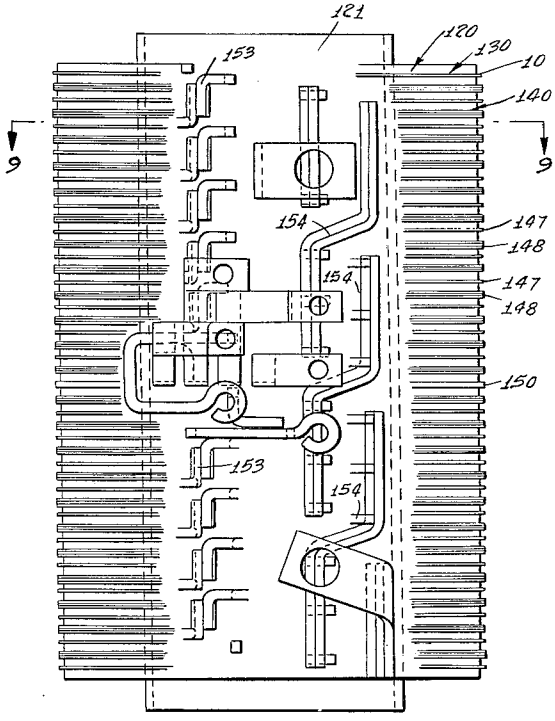


FIG. 6.

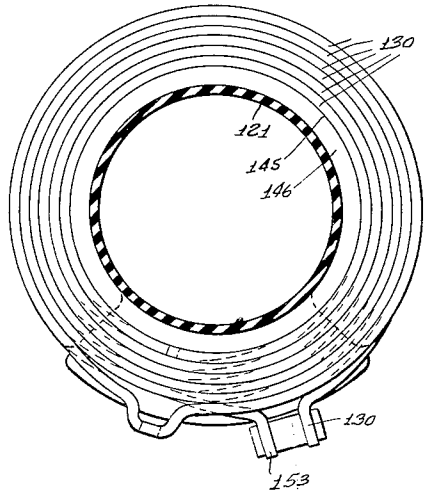


FIG. 9.

INVENTOR.
EDWARD JOHN DIEBOLD

BY
Ostrolenk & Faber

ATTORNEYS

Aug. 2, 1955 E. J. DIEBOLD 2,714,709

TRANSFORMER COOLING MEANS

Filed March 29, 1951 3 Sheets-Sheet 2

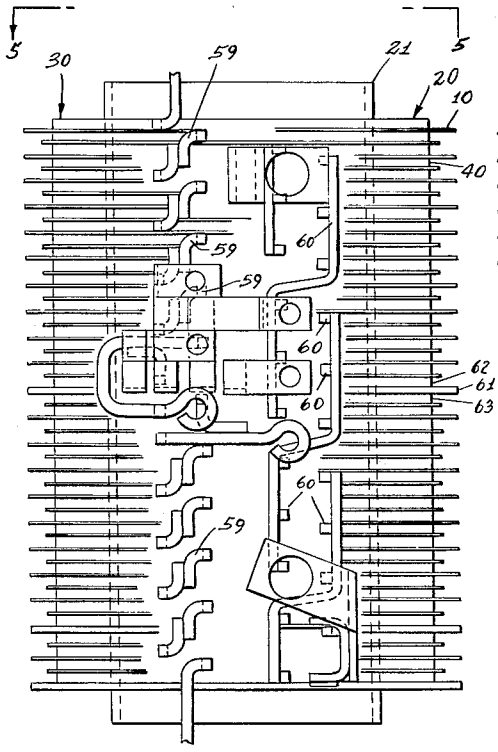


FIG. 2.

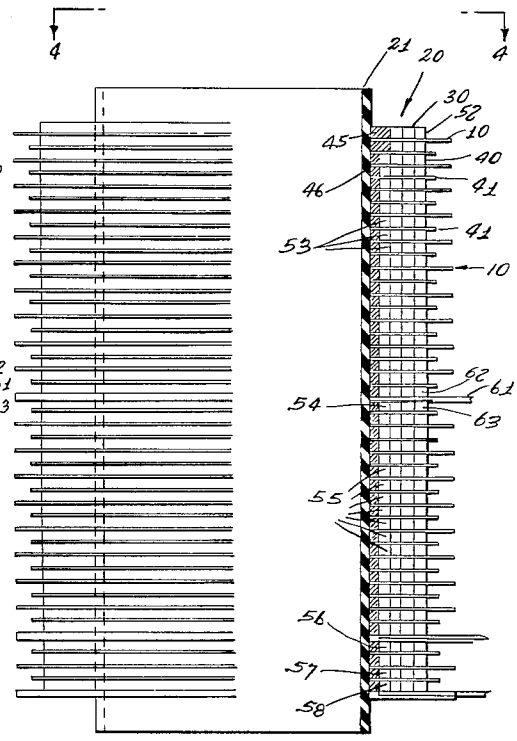


FIG. 3.

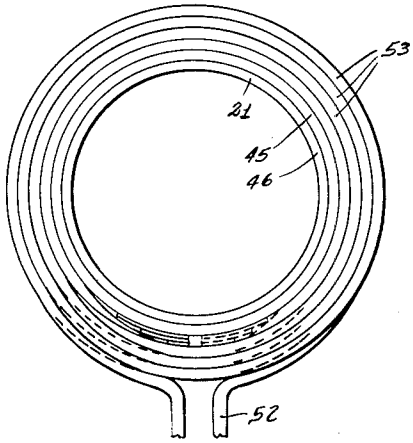


FIG. 5.

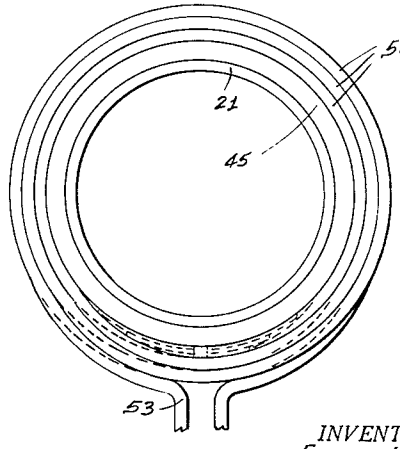


FIG. 4.

INVENTOR.
EDWARD JOHN DIEBOLD

BY

Detrolenk + Faber

ATTORNEYS.

Aug. 2, 1955 E. J. DIEBOLD 2,714,709

TRANSFORMER COOLING MEANS

Filed March 29, 1951 3 Sheets-Sheet 3

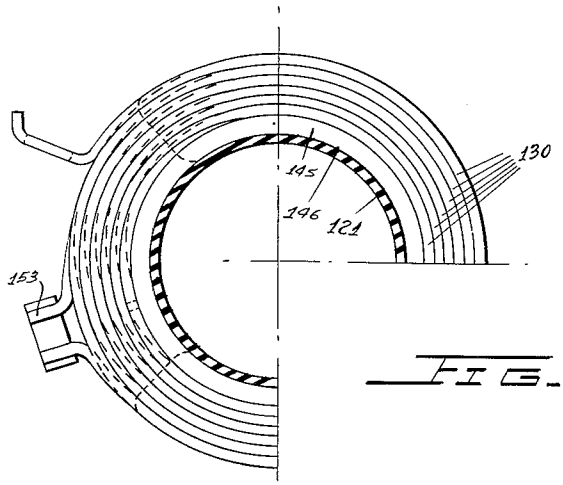


FIG. 8

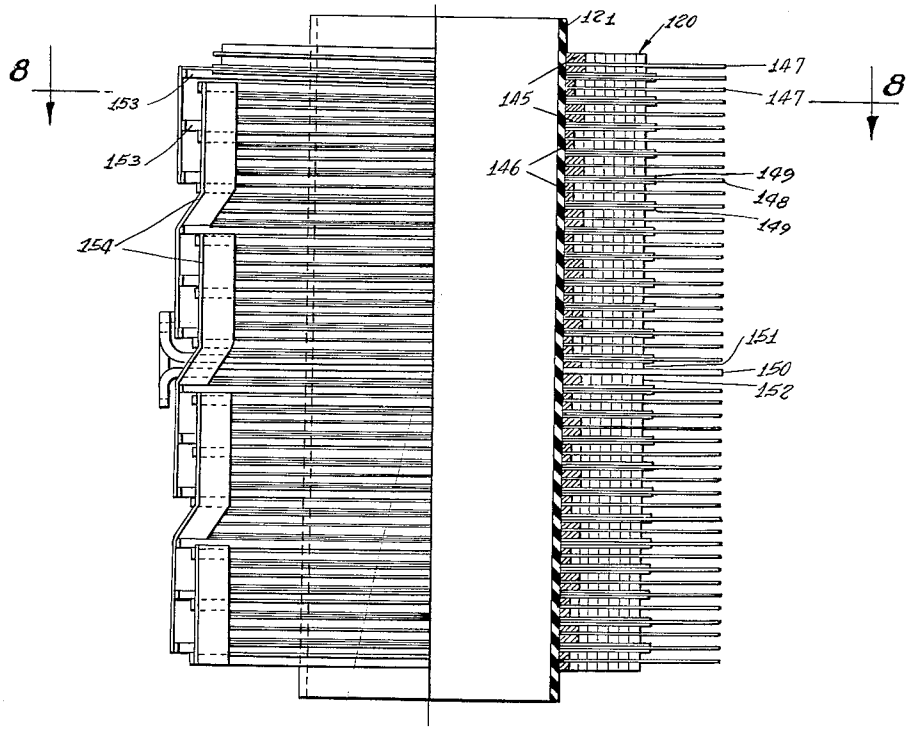


FIG. 7

INVENTOR.
EDWARD JOHN DIEBOLD

BY
Ostrolenk & Faber

ATTORNEYS

United States Patent Office

2,714,709

Patented Aug. 2, 1955

2,714,709

TRANSFORMER COOLING MEANS

Edward John Diebold, Ardmore, Pa., assignor to I-T-E Circuit Breaker Company, Philadelphia, Pa., a corporation of Pennsylvania

Application March 29, 1951, Serial No. 218,115

1 Claim. (Cl. 336—61)

My present invention relates to cooling means and more particularly it relates to transformer cooling means that produce cooling by a combination of heat conduction, convection and radiation.

It is well-known to persons familiar in the art that the output of any piece of electrical apparatus, i. e., generators, motors, transformers, etc. is limited by the rise in temperature caused by its losses. One of the most important problems is to provide some satisfactory means of cooling said equipment. In transformers the losses are mainly the so-called copper losses and core losses. When a current flows in a conductor, it carries an irreversible transfer of energy, in the form of heat, to the ambient surrounding the conductor. This irreversible transfer of energy is what constitutes the so-called "copper losses" and varies as the square of the current flowing in the conductor.

In transformers, copper losses are produced in the primary and secondary winding and vary as the square of their respective currents. The core losses are caused by the variation of the flux in the iron core and depend upon the frequency, the maximum value of the flux wave, the quality of the iron, the thickness of the lamination and the volume or weight of the core.

These losses vary almost as the volume while the amount of heat that can be dissipated depends upon the surface exposed.

More particularly, heat can be transferred in three different ways, that is, by conduction, convection and radiation.

Heat is transmitted by conduction when heat energy diffuses gradually through a mass of matter passing from particle to particle from the newer toward the older parts of a body.

Heat is transmitted by convection when heat is carried along by the motion of a stream of gas or liquid.

Heat is transmitted by radiation when heat energy is transmitted by waves.

The coils of most transformers are placed, therefore, in oil contained in cast iron or sheet steel tanks. To ensure effective cooling, the coil and core are so arranged that the heated oil may rise readily to the top through ducts between the coil and between the coils and the core. It will then pass down along the colder walls of the transformer core.

As only about one watt can be radiated from each 150 square inches of dry surface of ordinary transformer cases with smooth sides, for each degree centigrade rise in temperature, special means for cooling have to be provided except for the smallest transformers. Sufficient radiating surface can be obtained to keep transformers up to a few hundreds kws. cool by corrugating the sides of the cases. Corrugating or ribbing the sides of the cases increases the amount of heat radiated by about fifty per cent.

When cooling water is available, the most common means of keeping large transformers cool is to circulate water through coils of pipe placed in the tops of transformer cases in the oil above the windings. When this is done, corrugated containing cases are not necessary. Transformers for low voltage, i. e., not over a few thousand volts, may be air cooled.

In this case, no oil is used, but air is circulated through the coil by means of a blower. In many cases, or, for example, in unattended sub-stations, it is not possible to use artificial means of cooling. Under these conditions, special cases with very large radiating surfaces are used. The required increase in surface may be obtained by welding vertical tubes to the cases at the top and bottom.

In later types of cases for large self-cooled transformers radiating fins through which the oil can circulate are attached to the cases. Self-cooled transformers may be made, up to quite a few thousand kws. by the use of such devices.

My novel invention provides means for cooling a transformer by conduction, convection and radiation.

More specifically, my novel invention provides means for carrying away heat (copper losses) from the primary and secondary winding of a transformer by conduction and for dissipating said heat in the surrounding air or oil by convection and radiation, thus increasing the kva. of a transformer using these novel cooling means.

If further cooling is necessary, my novel invention provides means for using forced air or fluid circulation.

The main object of my present invention, therefore, is the provision of means for cooling transformer windings by conduction, convection and radiation.

Another object of my invention is the provision of means whereby the cooling means also insulates one winding layer from the other.

A further object of my invention is the provision of means whereby these cooling means can be easily mounted on the transformer coil.

Another object of my invention is the provision of means whereby the cooling effect can be easily increased by using forced air or fluid circulation.

These and other objects of my invention will become apparent in the following description and drawings in which:

Figure 1 is the plan view of an embodiment of my invention.

Figure 2 is the front view of a 13 kva. 230/45.5 volts transformer using the cooling means of my invention.

Figure 3 is a side view partly in section of the transformer shown in Figure 2.

Figure 4 is a plan view of a transformer coil shown in Figure 2 taken from line 4—4 of Figure 3 looking in the direction of the arrows, showing one layer of a six-turn two-layer coil.

Figure 5 is a plan view of a transformer coil shown in Figure 2 taken from line 5—5 of Figure 2 looking in the direction of the arrows showing one layer of an eight-turn two-layer coil.

Figure 6 is the front view of a 30 kva. 260/101.7 volts transformer using the cooling means of my invention.

Figure 7 is a side view partly in section of the transformer shown in Figure 6.

Figure 8 is a cross-sectional view of the transformer shown in Figure 6 taken from line 8—8 of Figure 7 looking in the direction of the arrows.

Figure 9 is a cross-sectional view of the transformer shown in Figure 6 taken from line 9—9 of Figure 6 looking in the direction of the arrows.

Referring first to Figure 1 showing the transformer cooling means of my invention, the cooling means 10 are made of a good heat conducting metal, like aluminum, and are so shaped that the cooling surfaces 11 between windings and cooling fins and the cooling surfaces 12 between cooling fins and air are very long and permit a good transmission of heat. The cross-section of fin 10 can be made

small because the heat conducting capacity of metals like aluminum is high.

In the particular embodiment of my invention shown in Figure 1, the cooling fins 10 have a circular recess 13 so that fins 10 can easily be placed around the tube 15. Because of opening 14, the cooling fins cover only about three-quarters of the circumference, the remaining quarter being used for winding connection or being later filled by an insulation spacer 16 as shown in Figure 1. Opening 14 also cuts the eddy current path so that no eddy current loss is produced by the presence of the cooling fins 10.

In order to ensure good electric insulation while providing passage for the heat, each fin 10 is covered by a layer of insulating material, like glass cloth, which is later impregnated with insulating varnish.

Referring now to Figures 2, 3, 4 and 5, showing a 13 kva. 230/45.5 volts transformer having the cooling fins of my invention, the coils 20 are centered by a tube 21 made of insulating material having sufficient mechanical strength to support coils 20, for example, "Bakelite." The coils 20 comprise the primary winding 30 and the secondary winding 40. Both windings are copper wires wound into flat pancake spools and are stacked alternatively on tube 21 with cooling fin 10 between each winding and a pressboard insulation 41 between each coil layer of the same winding.

More specifically, tube 21 is first surrounded by pressboard insulation 45, 46 of different thickness. Then the primary coils 30 and secondary coils 40 are placed around insulation 45, 46 of tube 21. All coils 30 and 40 are wound with cotton insulated square wire and in this particular embodiment the coils are as follows: The first coil 52 is a six-turn coil in two layers of three turns per layer as shown in Figure 4; the next nine coils 53 are eight-turn coils in two layers of four turns per layer as shown in Figure 5; then one four tap primary coil 54; folowed by eight coils 55 of eight turns in two layers of four turns per layer; next two half coils secondary 56 having each four turns; then one eight turn coil 57 in two layers of four turns per layer and finally one four-turn coil 58.

The coils constituting the primary winding 30 are connected together through soldered connections 59, while the coils constituting the secondary winding 40 are connected together through similar soldered connections 60.

As previously mentioned, each coil is separated from the previous and the next by a thin sheet of pressboard insulation 41, while cooling fins 10 are placed between coil layers.

A thicker cooling fin 61 can also be placed between appropriate layers of coils 62, 63. The heat then follows this path: from the windings of coils 52, 53, etc. to the surfaces 11 of cooling fins 10 by conduction, from surfaces 12 of cooling fins 10 to ambient air by convection and radiation.

Since fins 10 are made of good heat-conducting material after a relatively short period of operation, their temperature attempts to reach the average temperature of the windings 52, 53 etc. but since the ambient air or oil is at a lower temperature and a large section 12 of cooling fins 10 is immersed in this ambient air or oil, the temperature of the cooling fins 10 will not reach the average temperature of the windings 52, 53 etc. but will remain at a point of equilibrium corresponding to a temperature between the average temperature of the windings 52, 53, etc. and that of the ambient. The temperature gradient

$$\frac{dT}{dS}$$

is directed from the windings 52, 53, etc. to the cooling fins 10 in a direction approximately perpendicular to the fins 10. In the fins 10 it is directed outwardly from the tube 21 and in section 12 of fins 10 it is directed perpendicularly to the surfaces of the cooling fins 10.

If more cooling is needed, heat can be taken away from the fins 10 more rapidly by blowing air on the fins 10 by means of a fan.

Referring finally to Figures 6, 7, 8, 9 showing a 30 kva. 260/101.7 volt transformer having the cooling fins of my invention, the coils 120 are centered by a tube 121 made of insulating material having sufficient mechanical strength to support coils 120, for example, "Bakelite." Coils 120 comprise the primary winding 130 and the secondary winding 140. Both windings are copper wires wound into flat pancake spools and are stacked alternatively on tube 121: primary 130, cooling fin 10, secondary 140, cooling fin 10.

More specifically, tube 121 is first surrounded by pressboard insulation 145, 146 of different thickness. The coils 120 comprising primary winding 130 and secondary winding 140 are placed around pressboard insulation 145, 146 of tube 121. And finally cooling fins 10 are placed between each layer of coil 120.

More specifically, fin 10 actually comprises three types of cooling fins; the first type 147 without sheet insulation is placed between layers of the same coils, while the second type 148 with sheet insulation 149 is placed between each coil. A thicker and heavier cooling fin 150 can also be placed between appropriate layers as between layers 151 and 152. Here too the primary winding coils 130 are connected to each other by soldered connections 153, while the secondary winding coils 140 are connected to each other by similar soldered connections 154.

From a comparison of the two embodiments of my invention above shown, it is easily seen that the number of fins 10 in the second embodiment (Figures 6, 7, 8, 9) is greater than in the first embodiment (Figures 2, 3, 4, 5) because the kva. capacity of the second transformer is greater than in the first, that is, more heat is provided in the second transformer than in the first and hence more cooling is necessary.

For both embodiments the impregnation of the cooling fins 10 with insulating varnish is made when the transformer is fully assembled and after vacuum drying.

The finished transformer is mounted with the legs in a horizontal position such that the cooling fins 10 lie in a vertical plane and permit a free vertical flow of the air between them.

In the second embodiment the number of fins 18, 19 was increased with respect to the first embodiment because the kva. capacity of the second transformer is greater than in the first, that is, more heat is generated in the second embodiment than in the first.

In the foregoing I have described my invention solely in connection with specific illustrative embodiments thereof. Since many variations and modifications of my invention will now be obvious to those skilled in the art, I prefer to be bound not by the specific disclosures herein contained but only by the appended claim.

I claim:

In a transformer comprising a cylindrical core, a plurality of primary coils, a plurality of secondary coils, core insulation means, coil insulation means and cooling fins; said core insulation means being concentric with said cylindrical core and positioned on the outer peripheral surface thereof, said plurality of primary and secondary coils being positioned in concentric relation to said cylindrical core and being positioned around the outer periphery of said core insulation means, said core insulation means insulating said cylindrical core from said plurality of primary and secondary coils, each of said coils comprising a plurality of layers of pancaked electrical conducting windings, said coil insulation means being a pressboard insulation disc positioned between adjacent coils to electrically insulate each of said plurality of coils from the other coils, said cooling fins comprising a discontinuous aluminum disc, having a discontinuous sector therein to permit winding connections, said cooling fins being covered on both sides by an insulating varnish impregnated glass

cloth, said cooling fins being located between adjacent coil layers around said core insulation.

References Cited in the file of this patent

UNITED STATES PATENTS

591,869 Moody ---------- Oct. 19, 1897
714,232 Pichler ---------- Nov. 25, 1902
1,159,770 Hyde ---------- Nov. 9, 1915
1,602,043 Pfiffner ---------- Oct. 5, 1926
1,723,840 Burnham ---------- Aug. 6, 1929
1,938,421 Gilbert ---------- Dec. 5, 1933